Strathprints Institutional Repository

McNicoll, Iain and Kelly, Ursula and Marsh, Richard and McLay, David (2002) *Defining and identifying the knowledge economy in Scotland: a regional perspective on a global phenomenon.* University of Strathclyde, Glasgow, United Kingdom. ISBN 0-9542926-0-X

Defining and identifying the knowledge economy in Scotland

A regional perspective on a global phenomenon

Iain McNicoll

Ursula Kelly

Richard Marsh

David McLay

Acknowledgements and note on the Authors

Thanks are due to Mr Nigel Kay and Dr Deirdre Kelly for helpful comments on earlier drafts. This paper is the initial output of a new programme of interdisciplinary research on knowledge economy and ICT issues. The collaborative programme involves staff from across the university together with external partners to examine issues relating to the development of the knowledge economy and the impact of information and communications technologies. For further information on the knowledge economy programme please contact Ursula Kelly at the University of Strathclyde. (Tel: 0141-548 4206 and e-mail: u.kelly@mis.strath.ac.uk)

Note on the authors:

Professor Iain McNicoll holds the Chair of Applied Economics at the University of Strathclyde. He has over 25 years experience in modelling the Scottish Economy and in the development and application of input-output analysis for regional and national economies across the world.

Ursula Kelly is Policy and Communications Officer in the Information Resources Directorate and a member of the PReDICT Unit (Policy Research and Development in ICT for Education) at the University of Strathclyde.

Richard Marsh, formerly Research Fellow at the Fraser of Allander Institute, University of Strathclyde, is now an economic consultant with DTZ Pieda Consulting.

David McLay is an economics student at the University of Strathclyde.

ISBN: 0-9542926-0-X

Published by:
University of Strathclyde Publishing

Design and Print by:
Learning Services and the Universities' Design and Print Unit, University of Strathclyde

Contents

Introduction

The development and growth of a *knowledge economy* has become a key policy aim for governments in all advanced economies. This is based on recognition that technological change, the swift growth of global communications, and the ease of mobility of capital across national borders has dramatically changed the patterns of international trade and investment. The economic fate of individual nations is now inseparably integrated into the ebb and flow of the global economy.

When companies can quickly move capital to those geographical locations which offer the best return, a country's long term prosperity is now heavily dependent on its ability to retain the essential factors of production that are least mobile. This has led to a premium being placed on the knowledge and skills embodied in a country's labour force, as it has become a widely accepted view that a country which possesses a high level of *knowledge* and *skills* in its workforce will have a competitive advantage over others with a lower domestic skill base. Knowledge and skills are thought to be the basis for the development of a "knowledge economy."

However there remains considerable debate over how to define the knowledge economy and how to measure its size and growth. Knowledge itself is not easily defined or quantifiable, and the simple existence of knowledge *per se* does not automatically provide economic benefits. Rather, knowledge must be used and applied in appropriate ways for it to become an essential element in the development of a knowledge *economy*.

To assist in creating a framework for analysis, organisations such as the Organisation for Economic Co-operation and Development (OECD) have sought to develop definitions and statistical indicators for measuring the "knowledge economy", primarily using investment in the research and development of technology in manufacturing sectors as a way of measuring the spread of knowledge. Investment levels in higher education and the use of ICT in industries are also used by the OECD as supplementary indicators of the development of a knowledge economy in a given country.

Within the UK, the Department for Trade and Industry (DTI) and the Scottish Executive have adopted statistical measures of the UK knowledge economy compatible with the OECD indicators which can quantify, for example, the proportions of domestic employment in OECD-defined 'High Technology' and 'Medium Technology' sectors. In the course of undertaking this work, however, UK government agencies have also recognised that global definitions of a 'knowledge economy sector' do not necessarily directly correlate to 'knowledge economy' sectors at either a national or a regional level.

In the first instance, the OECD's definitions relate strongly to manufacturing processes and industries, whereas for many advanced economies, there is a strong prima facie case for believing that elements of their business (and even personal) service sectors would be integral components of their domestic "knowledge economies" on any sensible definition. Furthermore, even within manufacturing itself the OECD schema essentially classifies industries/commodities as "High Technology", "Medium Technology", etc, on the basis of *their total (i.e.world-wide) production factors content; including, in particular, their embodied total skilled labour content*. Whilst such a "global technological perspective" may be appropriate for organisations with an international remit such as the OECD, it is of far less immediate policy relevance to individual nations or regions, for which it is *the domestic factor content of the parts of the production chain in which they are actually involved* that defines and classifies local economic activities as part of the **domestic** "high technology" or "knowledge" industrial base.

In fairness, the OECD itself and UK government agencies have increasingly recognised that a narrow focus on "manufacturing" is excessively restrictive in the present context and the latter have endorsed a wider definition of the knowledge economy as: "one in which the generation and the exploitation of knowledge has come to play the predominant part in the creation of wealth, it is not simply about pushing back the frontiers of knowledge; it is also about the more effective use and exploitation of all types of knowledge in all manner of economic activity."[1]

Unfortunately, while this definition certainly encompasses a broad range of economic activity, its imprecision regarding what precisely is meant by "knowledge" means that it is arguably *too wide* to be very useful for policy purposes. Given that practically every form of human activity requires knowledge of some type or another, and that use of knowledge-embodying technology has become ubiquitous in almost all working processes in an advanced economy (be it a shop assistant using an electronic cash register or a road sweeper using a new cleaning machine), too broad a definition can lead to the conclusion that the knowledge economy is simply a synonym for any type of modern economic activity.

Furthermore, given this broad definition, agencies throughout the UK still tend to count industries or activities as elements of the domestic "high technology" or "knowledge" economies *if these industries have been so classified on a global basis*. At best this will give a misleading picture of the size and structure of the local knowledge economy, and at

[1] *Our Competitive Future: Building the Knowledge Driven Economy* DTI 1998

worst will lead to erroneous policy inferences being drawn. To take an example of potential relevance to Scotland and other UK regions, while the global embodied labour content of a computer may legitimately allow this product to be described as high technology, the stage of the production process involved in finally assembling all the "bits" into the finished article is certainly *not* high technology, requiring at most modestly skilled direct labour inputs. A region which specialises in computer assembly will find that associated demands for highly skilled indigenous labour are small, that opportunities for knowledge-based or technology-based spin-offs are negligible, and that the assembly activity itself may in due course relocate to another region or nation which can satisfy the same modest local skill requirements at a lower wage rate.

Of course, the other (and in the long run, more serious) side of the coin is that industries that are relatively specialised in the use of highly skilled indigenous labour, and hence are part of the region's knowledge/high technology economic base, may not be recognised as such. Development opportunities may be missed, and local activity levels in these sectors may even decline through unintended policy neglect.

Using Scotland as a case study, this paper seeks to develop definitions of "knowledge industries" which are workable and appropriate for an individual nation or region. Given such definitions, individual domestic industries can be classified as "knowledge", "hi tech" or otherwise *based on selected* **local** *technological characteristics*. More specifically, and briefly anticipating the discussion in Chapter 3, the fundamental characteristic underpinning the specific definitions adopted relates to *the level and type of domestic labour skills embodied in production*. That is, if a particular industrial activity in Scotland is relatively specialised in the employment of domestic workers who have high levels of "knowledge skills", then that activity can be classified as a *Scottish* knowledge industry and forms an integral part of *Scotland's* knowledge economy.

Compared to extant definitions (and the use made of them for classification by UK agencies), those presently proposed have two major advantages: (a) by defining on the basis of labour **input** characteristics, all industrial activity (whether primary, manufacturing, etc) may in principle be classified as a knowledge sector, and, inter alia, classifications based on **output** characteristics such as "weightlessness" are either subsumed or shown to be irrelevant; (b) by defining and classifying on the basis of **domestic** labour content, the true nature and scope of the local knowledge economy is revealed in a way which is both economically meaningful and policy relevant.

1. Global Knowledge Economy Indicators

The concept of the 'knowledge economy' is premised on an assumption that while knowledge, in some shape or form, has always been central to human and economic progress, in the modern era economies have become more dependent on the production, distribution and use of knowledge than ever before. The OECD has been at the forefront of developing statistical indicators for knowledge-related activity, and has sought to compile internationally comparable data so that the performance and progress of individual countries in the knowledge economy can be measured and evaluated.

In seeking to develop indicators which can capture the complex webs of relationships that may make up a knowledge-based economy, the OECD has identified over 160 indicators which may have potential value in pinpointing a country's position in a global context. These seek to reflect an extremely wide range of activity, tangible and intangible - from trends in R&D investment to the diffusion of information and communications technology and use of the internet, cross-border flows of investment, labour productivity, international trade and the mobility of human capital, among many others.[2] The sheer volume of indicators under development reflects the multifaceted nature of a knowledge economy and the difficulties inherent in defining and identifying where and how knowledge-based activity takes place.

1.1 Identifying 'Knowledge Industries'

Identifying indicators for specific sets of industries which can be classified as 'knowledge industries' and those which are most prominent in a knowledge economy has proved particularly difficult. The OECD has recognised technology-based activity as being of key importance in its measures of 'knowledge-based' industries, since technology is itself seen as embodied skill and knowledge. Initially focusing on the *producers* of technology, the OECD developed a set of indicators of 'high' and 'medium' technology manufacturing industries based on their relative R&D expenditures (or 'R&D intensity'). This classification of 'high' and 'medium' technology manufacturing industries has tended to be used by the OECD and others as the cornerstone of definitions of knowledge-based industries.

The OECD has subsequently supplemented the above baseline classification of knowledge industries with the inclusion of a limited number of 'market' service sectors that have been identified globally as being intensive *users* of high technology or ones which may

[2] *OECD Science, Technology and Industry Scoreboard: Towards a Knowledge-Based Economy* 2001

have a higher skilled workforce (reflected through occupational activity). The difficulty of identifying genuinely knowledge intensive industries relates to the limitations on data, particularly on service sector industries, since only those sectors on which internationally comparable data can be sourced are included in OECD definitions and measures.

Table 1: OECD Classifications of Technology and Knowledge Intensive Industries[3]

Manufacturing	**SIC 1992**	**Services**	**SIC 1992**
High Tech			
Pharmaceuticals	24.4	Post and Telecommunications	64.0
Office machinery and computers	30.0	Finance and Insurance	65.0,66.0,67.0
Aerospace	35.3	Business Activities (not including real estate)	71.0-74.0
Electronics-communications	32.0		
Scientific Instruments	33.0		
Medium High Tech			
Motor Vehicles	34.0		
Electrical Machinery	31.0		
Chemicals	24.0 (excluding 24.4)		
Other Transport Equipment	35.2, 35.4, 35.5		
Non-Electrical Machinery	29.0		

Education and Health are also considered by the OECD to be knowledge intensive services, although complete data is not yet available across all countries.

There is an immediate difficulty in relating these OECD indicators to activity at a regional level. The OECD is attempting to observe international trends against a

[3] *Ibid.*

common baseline to enable policy-makers to chart the progress of their country against a global benchmark. The classifications are based on the total R&D intensity and the trend towards intensive or higher skilled use of technology across a number of OECD countries. They are not designed to enable one to focus in on the pattern of activity at a national or sub-national level.

Simply applying the OECD definitions of 'knowledge industries' derived on a global basis to the composition of a regional economy will identify regional activity that, on the face of it, forms part of the overall 'global knowledge chain'. However it does not reveal any information about regional specialisation within that chain. One nation or region may predominate in high skilled research and development, another may simply be using lower skill to assemble or use the outputs of other regions or nations. Even within a single OECD country and within a single industrial sector different regions may have very different profiles of activity.

If a region's only claim to be part of a particular high technology industry is that of assembly plant activity, the ease with which such plants can be located and relocated could lead to a particular region appearing to move in and out of the 'knowledge economy' practically overnight . However the movement of this link of the knowledge chain has no effect at all on the global indicators - since the knowledge chain itself still exists.

Moreover since the global indicators are limited to those on which internationally comparable data is available, it is entirely possible that a region may specialise in a form of high skilled activity which is not currently measured at the international level. By relying too heavily on OECD definitions of 'knowledge industries', regional policy-makers may overlook domestic seams of knowledge-based activity which could have the potential for growth.

1.2 Domestic knowledge economy indicators

Current UK and Scottish approaches to the knowledge economy have sought to build on the OECD definitions to develop indicators of domestic knowledge economy activity which can inform policy. In Scotland a variety of both input and output measures are under consideration and considerable policy emphasis has been placed on encouraging research and innovation(particularly the potential for scientific knowledge transfer from universities into the surrounding economy), raising productivity, generally raising the skills of the workforce as well as encouraging e-commerce and the use of information and communications technology. The Scottish Executive is also seeking to identify a 'knowledge-based industry index' including OECD-defined 'High Technology' industries together with industries that "purchase technology and are typically highly automated"[4].

Table 2: Summary of knowledge economy definitions framing current Scottish policy[5]

OECD Measures of high tech sectors	OECD measurement: proportionate spending within	Scottish Executive definition	Scottish Executive measurement at firm level
High tech Pharmaceuticals SIC 24.4 Office machinery & computers SIC 30.0 Aerospace SIC 35.3 Electronics-communications SIC 32.0 Scientific instruments SIC 33.0 **Medium High Tech** Motor vehicles SIC 34.0 Electrical machinery SIC 31.0 Chemicals SIC 24.0 (excluding 24.4) Other transport equipment SICs 35.2, 35.4, 35.5 Non-electrical machinery SIC 29.0	Public Sector education spending as a proportion of GDP. Research & Development (GERD) Expenditure on Software ICT Employment Value added by ICT sector ICT R&D ICT trade	Acceptance of the OECD definition across: SICs 24.4, 30.0, 35.3, 32.0, 33.0, 34.0, 31.0, 24.0, 35.2, 35.4, 35.5, 29.0 Additional firms that exhibit a global position	Acknowledgement of OECD measures Rate of growth & productivity within the individual firm e-transactions Proportion of expenditure spent upon R&D Development of Global HQs Export volumes Proportion of expenditure spent upon in-work training

However, while there has been a considerable body of effort and a number of 'task forces' set up to examine the key issues for the development of a Scottish knowledge

[4] Scottish Economic Statistics 2002

[5] Sources: Compiled from *Scottish Economic Statistics 2001, Measuring progress towards a Smart Successful Scotland 2001, Framework for Economic Development in Scotland 2000 etc.*

economy (such as the *Framework for Economic Development in Scotland*, the *Smart Successful Scotland* strategy, the *Knowledge Economy Taskforce*, the *Scottish Executive Cross-cutting Knowledge Economy Report*) it is clear that efforts to develop knowledge economy indicators for Scotland are still at a very early stage. There remains a heavy reliance on the OECD measures, which is likely to weight any definition of Scotland's knowledge economy in favour of manufacturing industries. Very few indicators for knowledge industries have so far been proposed that could enable closer observation of the activity in sectors other than manufacturing.

Equally, while the general level of skill in the Scottish Labour Force has been identified as an important issue, no attempt has yet been made to measure the skill and knowledge content of industries in Scotland. The extant indicators in use are therefore preliminary and require substantial further refinement.

There is another problem associated with reliance on OECD indicators alone which is that these are something of a moving target; since they are developed on the back of global data becoming available and (quite properly in their context) are constantly being changed and refined, industries can move between medium and high technology classifications and service sectors can come in and out. (E.g.'Real Estate' was included in the 1999 OECD Science and Technology scoreboard but excluded in 2001). However if a more fundamental set of indicators for regional use could be developed, premised on domestic knowledge content, rather than on global knowledge content, policy-makers may be less vulnerable to the vagaries of shifting global data availability. Additional definitions and potentially more stable ways of identifying actual and potential Scottish knowledge-based industries are needed in order to develop a more comprehensive set of knowledge economy indicators for policy use.

2. The underlying fundamentals: defining and identifying knowledge

In order to determine which Scottish industries are genuinely knowledge based and which may make up Scotland's knowledge economy, it is necessary to take a step back and define what knowledge is, and how it can be recognised and measured.

2.1 Defining Knowledge

Lundvall and Johnson (1994)[6] identified distinctions between four different types of knowledge and whether these are forms of 'codified' or 'tacit' knowledge - *Know-what, Know-why, Know-how and Know-who*.

2.11 Codified Knowledge: *Know-what and Know-why*

Codification of knowledge refers to a process whereby knowledge is transformed into information through a process of reduction and conversion.[7] Information itself is data that has been processed into a form that is meaningful to the recipient.

- *Know-what* is a form of codified knowledge that relates to knowledge about *facts* e.g. What is the temperature of water at boiling point? What is the capital city of Argentina?

- *Know-why* refers to scientific knowledge of the principles and laws of nature underlying *why* something happens. For example, Newton's Law of Gravity explains (to a very high degree of accuracy) the nature of the observed orbits of the planets around the sun.

These types of codified knowledge are most often gained through the process of formal education, since education is itself a method of transmitting such knowledge.

This makes codified knowledge relatively easy to measure, since an individual's formal educational achievements can be used to signal the possession of certain types of knowledge and the ability to handle similar types - both in terms of subject specialism and level of attainment. One would not expect a person educated only to basic school-leaving qualifications or with a degree in history to know about complex chemical processes. However one would assume that a chemistry graduate *would* have such knowledge.

[6] Lundvall B.A,Johnson B *The Learning Economy* Journal of Industry Studies 1994 Vol. 11 No.2

[7] Foray D, Lunvall B.A *The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy* Employment and Growth in the Knowledge-Based Economy OECD 1996

2.12 Tacit knowledge

Tacit knowledge describes types of knowledge which tend to remain embodied within an individual or implicit within a knowledge network and which are more difficult to identify and measure.

Know-how refers to skills, often gained through practical experience. Many types of innovation are dependent on the *know-how* of individuals to take existing information and ally it to new ideas. For example, software developers are in essence using their knowledge and experience of extant technology to innovate and produce new applications. They are also expanding their knowledge base when applying existing knowledge to the new application in order to determine how the new system performs. However neither the initial development or the interpretation of the new technology is codified. The developers are using *tacit* knowledge, which cannot easily be replicated because it has not been stated in explicit form.

The extent to which an individual possesses this form of knowledge is difficult to measure. It is also difficult to track the ways in which tacit knowledge can subsequently be codified and made explicit. Eliasson (1990)[8] has observed that while research and innovation rapidly create new tacit knowledge, the educational level of the receiver determines how quickly such knowledge can be transmitted. The educational and technological level of a production system also determines how efficiently a new knowledge base can be turned into industrial applications. This suggests that while *know-how* may be different from *know-what* and *know-why*, the effectiveness of *know-how* within a knowledge economy is related to the surrounding levels of *know-what* and *know-why*. This implies that all means of obtaining knowledge and all educational processes are important whether formal schooling or on-the job training. This also leads into the role of *know-who*.

Know-who refers to knowledge networks, where the sharing of knowledge and collaboration among similar groups can lead to a growth in the knowledge base. This is often the underlying rationale behind the promotion of industrial 'clusters', which seek to bring 'knowledge buyers' together with 'knowledge sellers' in an attempt to encourage knowledge or technology transfer. 'Knowledge buyers' may be looking for insights and judgements to assist them to accomplish a task more efficiently. 'Knowledge sellers' are individuals or organisations (such as other firms, research laboratories or universities) with substantial knowledge about a process or subject.

[8] Eliasson G et al *The Knowledge Based Information Economy* Stockholm 1990

It can be suggested that the development of a successful 'knowledge economy' depends on the existence of all of these forms of knowledge, codified and tacit, brought together in a networked knowledge chain. They work best together and not in isolation. Their existence may explain agglomerations of skill, whereby the outputs of a group of similarly skilled people may be greater than the sum of their individual and separate outputs.

2.2 Identifying and measuring knowledge capacity

2.21 Using National Vocational Qualifications as a measure of accumulated knowledge

It has already been highlighted that formal educational attainment and certification can be used to some extent as a proxy for measures of *know-what* and *know-why*, but *know-how*, which is more frequently gained through learning by doing, learning by using and learning by interacting, is more difficult to identify and measure.

However there has been a trend across OECD countries to seek to offer individuals alternative means for recognising and validating their acquired skills and knowledge. In the UK this was done through the introduction of National Vocational Qualifications (NVQs) in the late 1980s. The rationale behind NVQs was to enable a way of measuring the skills base of the workforce:

A system was needed that would recognise the skills people already had and that was consistent, reliable and well structured. It would allow the skills-base of the country and success in upskilling the whole of the national workforce to be measured. Qualifications needed to be realistic and accessible with scope for progression[9]

In essence a National Vocational Qualification (Scottish Vocational Qualification or SVQ in a Scottish context) is a statement of competence that is intended to facilitate entry into or progression within employment, further education or training. The statement of competence incorporates specific standards - the ability to perform a range of work-related activities and the possession of levels of skill, knowledge and understanding that underpin performance in employment. New skills frameworks have been developed which also enable other formal educational qualifications to be expressed in terms of NVQ equivalence.[10]

[9] *History and Background to National Vocational Qualifications* Department for Education and Skills www.dfes.gov.uk/nvq.history/shtml

[10] See: *An introduction to the Scottish Credit and Qualifications Framework (SCQF)* 2001 http://www.sqa.org.uk

NVQs therefore provide a means of measuring levels of skill among the workforce which capture elements of *know-how* as well as those relating to *know-what* and k*now-why*.

2.22 Using Occupational position as a signal of skill

Another potential indicator of the possession of certain skills is a person's actual occupational position. The occupational task one performs offers a supplementary measure of one's capability to apply one's *know-how* and the nature of the skill involved. This can be seen more clearly through an example.

Recently, Microsoft launched its new operating system Microsoft XP. The launch of the software presents an opportunity for individuals to upgrade their skills. Who is best placed to achieve this upgrading of skills, those reliant solely upon the education system for skill conferment or those employed in a particular occupational group? A certificate of competence in Microsoft XP is only possible once the tacitness accumulated within the individual know-how has been codified and packaged. The time-lag between the new software being codified and packaged ready for students to formalise their learning will, even by conservative estimates, be superseded by the launch of another software development. The pace of technological development therefore renders the prospect of Microsoft XP becoming part of the education system's codified syllabus unlikely. Even if it does it will probably arrive at a time when technology has moved on and the merits of obtaining the accreditation have diminished. Formal education in this context does not provide the most efficient method of skill accumulation.

One would rationally expect those directly involved in an occupation that requires everyday interaction with computer software to upgrade their computing skills more easily than someone employed in an activity with limited computer-related occupational requirement. Therefore the occupational position that an individual holds will impact upon their propensity to accumulate new and enhance existing skills.

In relation to the accumulation of ICT-related skills particularly, this might be regarded as being of particular importance in the development of a knowledge economy - since the use of ICT can speed up the process of both transmitting and receiving information.

3. A new approach to defining and identifying Scotland's knowledge economy

3.1 Identifying Scotland's knowledge capacity

In seeking to identify which Scottish industries are genuinely involved in 'the knowledge business' and are integral to Scotland's knowledge economy, it is necessary to define new criteria and new measures which can indicate where *Scotland's* knowledge capacity is to be found. In order to do this one needs to identify the actual Scottish knowledge content of their goods and services.

Building on previous work carried out by the authors, including the development of a Scottish Labour Market Intelligence Model,[11] four new measures are proposed. These measures seek to identify indicators of the levels of *know-what*, *know-why* and *know-how* currently existing in Scottish industry, while one particular measure (Measure Three) begins to provide some limited evidence on the existence of *know-who* knowledge activity. The measures then enable a ranking of industries to be compiled according to the evidence of the Scottish skill content embodied in the goods and services they produce. This ranking can be interpreted as a preliminary 'league table' of Scottish knowledge industries.

It is beyond the scope of this paper to develop detailed evidence for indicators of networked knowledge or *know-who* currently operating within the Scottish economy. However a more precise method of measuring inter-industry knowledge flows is currently being developed by the authors.[12]

3.2 Measure One: The Average NVQ level of Scottish labour inputs

As previously discussed, evidence of formal educational achievement provides a basis from which an individual's level of knowledge or competence in handling different types of codified information can be inferred. However formal education alone does not capture other elements of knowledge, particularly that which is tacit and resides within an individual's

[11] McNicoll I, Melling M and Marsh R: *The Scottish Labour Market Intelligence Project* 1999 and McNicoll I, Marsh R, Kelly U *The Scottish Labour Market Intelligence Model Professional Edition* 2001 The SLMI model is an input-output based operational model of the Scottish economy, which incorporates a Labour Market satellite. It uses real Scottish data, derived from Scottish Executive Input-output tables and the Labour Force Survey. The version of the SLMI used here pooled data from 1995 –1997 to form the 'base economic year' on which studies can be undertaken and a complex and sophisticated range of labour and skills forecasts can be made.

[12] *A proposed Inter-Industry Skills Accounting Framework, with an empirical application to Scotland,* McNicoll I, Marsh R and Kelly U

personal experience and accumulation of skills, often gained through working practice rather than formal training. However the development within the UK of alternative measures of competence or ‘know-how’ through a National Vocational Qualification framework provides a wider range of indicators as to a person’s actual competence and degree of skill. Formal levels of education can be subsumed within the NVQ framework since it includes both an analysis of the levels of competence within each NVQ classified level and an indication of where certain formal qualifications may be deemed broadly equivalent. There are 6 NVQ levels of competence, ranging from 0, which indicates no recognised skill, through to Level 5, which indicates a very high level of skill.

Appendix Two gives the full definitions of each level of competence and the equivalence of formal qualifications within the framework. Broadly speaking, NVQ Level 2 indicates a competence and skill equivalent to that achieved through basic school-leaving qualifications; Level 3 and above indicates achievement beyond the level of compulsory schooling, Level 4 is broadly equivalent to first degree level with the highest Level 5 deemed equivalent to achievement of higher degree or beyond. However, it is important to re-emphasise that an individual recognized as having a certain NVQ level of skills *need not* have *formal* education certification attesting to the fact.

While certain types of knowledge may always remain tacit and cannot be measured, the NVQ framework provides the best extant set of indicators as to a person’s level of skill and knowledge capacity.

The authors used the previously developed Scottish Labour Market Intelligence Model to analyse the NVQ levels of the Labour force across 56 industries, which in aggregate cover the entirety of Scottish economic activity.

Table 3: Industry rankings of average NVQ skill level. Classification of 56 Input-Output groups. Top 30 Industries ranked.

SIC	Ranking	Description	Ave NVQ
73	1	Research and Development	3.49
72	2	Computing Services	3.35
80	3	Education	3.23
66	4	Insurance and Pension Funds	2.85
67	5	Auxiliary to Insurance and Financial Services	2.82
40	6	Gas and Electricity Production and Distribution	2.74
11,12	7	Extraction - Oil and Gas	2.73
33	8	Medical and Precision Instruments	2.69
41	9	Water Supply	2.63
74	10	Business Services	2.59
75	11	Public Administration	2.58
85	-	Health, Social Work and Veterinary Services	2.58
65	13	Banking, Financial Intermediation	2.57
70	14	Owning and Dealing in Real Estate	2.56
35	15	Building and Repair of Sea, Air and Spacecraft	2.55
29	16	Machinery, Tools and Appliances	2.52
23	17	Oil Processing, Nuclear Fuel	2.50
22	18	Printing and Publishing	2.46
16	19	Tobacco	2.44
61	20	Water Transport	2.41
24	21	Chemical Products	2.39
28	-	Fabricated and Structural Metal Products	2.39
91	23	Membership Organisations	2.38
45	24	Construction	2.34
71	25	Renting of Machinery	2.31
10	26	Coal Extraction etc	2.30
25	27	Rubber and Plastic Products	2.28
64	28	Postal and Telecommunications Services	2.27
92	29	Recreational Services	2.26
27	-	Basic Metal Goods	2.26

As Table 3 shows, the five industries with the highest average NVQ level are all service sector rather than manufacturing industries. The average NVQ level covers all of the workforce across all of the occupations employed in that industry.

This measure is indicative of the overall skill level within a particular industry, however as an average it covers all occupations employed within the industry.

Clearly the higher the overall level of skill within an industry the more likely it is to be engaging in activities that are genuinely knowledge-based. A second measure can be made to identify which industries have a requirement for the very highest levels of skill.

3.3 Measure Two: Proportion of employees with NVQ level 4/5

NVQ levels 4 and 5 are equivalent to first and higher degree level education. These are the highest levels of skill that can be measured under this system. Industries with a high proportion of employees possessing this degree of skill are relatively specialised in the use of *embodied labour knowledge*.

Table 4: Industry rankings of proportion of employees with an NVQ level of 4 or 5. Classification of 56 Input-Output groups. Top 30 Industries ranked.

SIC	Ranking	Description	%
80	1	Education	61.33%
72	2	Computing Services	60.83%
73	3	Research and Development	60.23%
85	4	Health, Social Work and Veterinary Services	38.88%
66	5	Insurance and Pension Funds	34.36%
40	6	Gas and Electricity Production and Distribution	31.96%
74	7	Business Services	31.71%
11,12	8	Extraction - Oil and Gas	31.70%
7	9	Auxiliary to Insurance and Financial Services	30.97%
33	10	Medical and Precision Instruments	29.91%
41	11	Water Supply	29.14%
70	12	Owning and Dealing in Real Estate	28.93%
24	13	Chemical Products	27.38%
91	14	Membership Organisations	26.07%
29	15	Machinery, Tools and Appliances	24.32%
75	16	Public Administration	23.62%
65	17	Banking, Financial Intermediation	22.95%
32	18	Electronic Components	22.46%
30	19	Office Machinery and Computers	21.89%
23	20	Oil Processing, Nuclear Fuel	21.71%
22	21	Printing and Publishing	20.04%
16	22	Tobacco	19.56%
35	23	Building and Repair of Sea, Air and Spacecraft	19.35%
31	24	Electrical Equipment	19.04%
92	25	Recreational Services	18.92%
25	26	Rubber and Plastic Products	18.42%
14	27	Extraction - Metal Ores and other mining and quarrying	18.35%
90	28	Sanitary Services	18.16%
64	29	Postal and Telecommunications Services	17.65%
10	30	Coal Extraction etc	17.24%

As Table 4 demonstrates, the five industries with the highest proportion of employees possessing NVQ Levels 4 and 5 once again are revealed to be service sectors. Compared with Table 3, there is some variation in sector-specific rankings, with Health, Social Work and Veterinary Services entering the top five at the expense of Auxiliary Financial Services. It can be observed that while Computing *Services* (SIC 72) ranks number 2 in Scotland for the proportion of its labour force with the highest levels of qualification (nearly 61%), Computer *Manufacturing* (SIC 30 Office Machinery and Computers) ranks much lower at 19th place with only around 22% of its workers possessing NVQs 4 and 5.

If one returns to Table 3 and examines the average NVQ level in these industries it can be observed that, while Computer Services is also number 2 in terms of overall industry skill level, Computer Manufacturing does not feature at all in the top 30 industries ranked.

This would seem to suggest that the type of work required within the Scottish Computing Services industry which includes, for example, design and maintenance of computing systems, IT consultancy etc has a significantly greater labour knowledge requirement than that of the Scottish Computer Manufacturing Industry. It is a moot question whether an industry, formally classified as an OECD high technology sector, but which has an overall revealed *domestic* skilled labour input of less than basic school-leaving qualifications, can be considered part of the existing Scottish knowledge economy for policy purposes.

3.4 Measure three: Ratio of NVQs Sold / NVQs bought

The two measures presented above are indicators of the actual skilled labour utilised in the industries listed. Fundamentally, these are reflections of the quality and quantity of the direct labour *inputs* embodied in a sector's own *output*.

However, every industry also buys inputs in the form of local goods and services in order to produce its own particular outputs, *and Scottish skilled labour in the domestic supplying sectors is embodied in these operating purchases of commodities*. This represents a particular industry's **indirect** use of Scottish skilled labour. The volume of domestic skilled labour indirectly embodied in Scottish products can be empirically estimated, since the SLMI model referred to earlier[13] contains a government-produced Input-Output table for Scotland which details domestic inter-industry transactions in goods and services. Combining this information with the appropriate skilled labour/output coefficients (again derived from official statistics) provides

[13] McNicoll I, Melling M and Marsh R *The Scottish Labour Market Intelligence Project* 1999
McNicoll I, Marsh R and Kelly U *The Scottish Labour Market Intelligence Model Professional Edition 2001*

quantification of Scottish inter-industry trade in terms of embodied skilled labour content.

While a fully operationalised Social Accounting Matrix articulated in terms of a skills/ knowledge numeraire could be extremely valuable for a variety of policy-related purposes,[14] in the present paper estimates of the average skill levels of each industry's direct and indirect labour content are used to construct an indicator which allows industries to be ranked in terms of their degree of *domestic skill augmentation*. Specifically, a "Skill Added" ratio is defined for each sector as:

Skill Added Ratio (i) = Average NVQ level of i's own workforce/ Average NVQ level embodied in i's domestic intermediate purchases.

A sector with a Skill Added Ratio (SAR) greater than unity is *domestically skill augmenting*, in the sense that its own workforce is adding a higher average level of skills to its products than that which is embodied in its purchases of local goods and services needed to produce those products. Conversely, an industry with a SAR<1 is *domestically skill diluting*, in that it is directly contributing a "lower" average level of skills to the "higher" level embodied in its operational expenditures on local materials, services, etc. Clearly, in this context an industry with a SAR value of unity is *domestically skill neutral*.

Calculated SAR values for the top 30 Scottish industries, and the average NVQ level values from which they are derived, are given in Table 5. It can be seen that the rankings in Table 5 are similar to those in Table 3 (though the increase of a *manufacturing* sector, Medical and Precision Instruments, to a top 5 ranking may be noteworthy). Closer inspection of the data indicates that this outcome is largely explained by the fact that, while SAR numerator values reflect *sector-specific labour technology characteristics* and thus are highly variable, the SAR denominator values reflect the embodied skill contents of a wide variety of commodity inputs and hence tend to reflect *economy-wide labour technology characteristics*, resulting in a range of calculated values scattered fairly narrowly around the all-Scotland base year average NVQ level of 2.34.

Given this all- Scotland base year value, it can also be seen from Table 5 that a number of industries (for example, Banking et al and Public Administration), which are classified as

[14] A working paper *(A proposed Inter-industry Skills Accounting Framework, with an empirical application to Scotland* – McNicoll I, Marsh R and Kelly U) defines and describes a framework for a Skilled Labour Accounting Matrix (SLAM), and constructs Scottish SLAMs using both FTE job and skill unit numeraires. The paper also explores possible modelling uses of the SLAM, including analyses of the **transmission** of embodied knowledge/skills.)

essentially “skill neutral” according to the SAR indicator, in fact had higher-than-average labour skills directly producing their outputs *and* had higher-than-average labour skills embodied in their commodity inputs. Clearly, on a prima facie basis, such sectors are candidates for inclusion in the domestic “knowledge economy”; indeed, closer examination of the nature and level of the embodied skill content of the bilateral trade in products among individual industry pairs may assist in the identification of local “knowledge” or “skill” *clusters.*[15] For present purposes, the important point to emphasise is the danger of classifying an industry as a particular type on the basis of any single metric.

Table 5: The Skills balance: ratio of NVQs sold/bought

SIC	Ranking	Description	Ave NVQ Bought	Ave NVQ Sold	Ratio
3	1	Research and Development	2.36	3.49	1.47
72	2	Computing Services	2.50	3.35	1.34
80	3	Education	2.47	3.23	1.31
67	4	Auxiliary to Insurance and Financial Services	2.39	2.82	1.18
33	5	Medical and Precision Instruments	2.33	2.69	1.16
85	6	Health, Social Work and Veterinary Services	2.24	2.58	1.15
66	7	Insurance and Pension Funds	2.51	2.85	1.13
11,12	-	Extraction - Oil and Gas	2.42	2.73	1.13
40	9	Gas and Electricity Production and Distribution	2.48	2.74	1.11
74	10	Business Services	2.42	2.59	1.07
35	-	Building and Repair of Sea, Air and Spacecraft	2.39	2.55	1.07
41	12	Water Supply	2.49	2.63	1.05
29	-	Machinery, Tools and Appliances	2.39	2.52	1.05
22	14	Printing and Publishing	2.35	2.46	1.04
70	-	Owning and Dealing in Real Estate	2.46	2.56	1.04
28	16	Fabricated and Structural Metal Products	2.33	2.39	1.03
61	-	Water Transport	2.35	2.41	1.03
24	-	Chemical Products	2.33	2.39	1.03
92	19	Recreational Services	2.22	2.26	1.02
65	20	Banking, Financial Intermediation	2.54	2.57	1.01
91	-	Membership Organisations	2.37	2.38	1.01
16	22	Tobacco	2.43	2.44	1.00
23	-	Oil Processing, Nuclear Fuel	2.49	2.50	1.00
75	-	Public Administration	2.57	2.58	1.00
10	-	Coal Extraction etc	2.30	2.30	1.00
32	-	Electronic Components	2.26	2.26	1.00
45	-	Construction	2.35	2.34	1.00
71	28	Renting of Machinery	2.33	2.31	0.99
30	-	Office Machinery and Computers	2.20	2.18	0.99
93	-	Other Service Activities	2.23	2.22	0.99

[15] This point is explored in more detail in the paper referred to in footnote 14

3.5 Measure Four: Proportion of Employees in occupations with a high ICT content.

This paper has earlier suggested that occupational position can itself signal a relatively high degree of skill, and also the *nature* of that skill. In relation to the development of a knowledge economy it is sometimes considered that ICT diffusion across the economy (the use of ICT) is as important as direct engagement in an ICT industry *per se*. It could therefore be suggested that industries which have a significant proportion of employees engaged in occupations which have a high ICT content are more likely to have a body of tacit skill and knowledge in relation to the use of ICT which is not necessarily captured under more traditional measures of skill.

A fourth measure is therefore proposed, which is to identify the industries which are likely to have a high degree of ICT knowledge, perhaps tacit as well as explicit. This is done by observing the proportion of employees in ICT -related occupations across Scottish industry. For these purposes ICT-related occupations were defined as Standard Occupational Classifications (SOC):

SOC **126** (computer systems managers etc),
SOC **214** (software engineers),
SOC **320** (computer analysts/programmers),
SOC **490** (computer etc operators)
SOC **526** (computer engineers)

Table 6: Proportion of Employees involved in ICT (SOC126, 214, 320, 490 & 526). Classification of 56 Input-Output groups. Top 30 industries charted.

SIC	Ranking	Description	Proportion of Employees involved in ICT
72	1	Computing Services	58.82%
66	2	Insurance and Pension Funds	11.20%
30	3	Office Machinery and Computers	11.06%
40	4	Gas and Electricity Production and Distribution	8.94%
73	5	Research and Development	7.79%
65	6	Banking, Financial Intermediation	7.65%
64	7	Postal and Telecommunications Services	6.37%
14	8	Other Mining and Quarrying	5.56%
33	9	Medical and Precision Instruments	5.26%
62	10	Air Transport	5.00%
31	11	Electrical Equipment	4.85%
22	12	Printing and Publishing	4.35%
67	13	Auxiliary to Insurance and Financial Services	3.67%
32	14	Electronic Components	3.31%
11,12	15	Extraction - Oil and Gas	2.78%
90	-	Sanitary Services	2.78%
61	17	Water Transport	2.50%
23	18	Oil Processing, Nuclear Fuel	2.44%
29	19	Machinery, Tools and Appliances	2.31%
21	20	Paper and Board Products	2.27%
15	21	Food and Drink	2.26%
35	22	Building and Repair of Sea, Air and Spacecraft	2.13%
93	23	Other Service Activities	2.04%
75	24	Public Administration	1.90%
74	-	Business Services	1.90%
24	26	Chemical Products	1.12%
50	27	Distribution and Motor Repair, etc	1.09%
92	28	Recreational Services	1.01%
28	29	Fabricated and Structural Metal Products	0.92%
70	30	Owning and Dealing in Real Estate	0.89%

This indicator gives a slightly different picture from the other measures adopted. Unsurprisingly given the nature of its outputs, Computer Services has a far higher proportion of its workforce in defined ICT occupations than any other sector. Perhaps more interesting is that only nine other industries had more than 5% of their employees directly engaged in ICT-related occupations. This could suggest a relatively low capacity for the development of tacit ICT knowledge in Scottish industries. Given the policy trend towards encouraging the expansion of e-commerce and related activity which requires a relatively high degree of ICT expertise in terms of setting up and maintaining appropriate systems, the fairly low proportion of employees in ICT-related occupations across Scottish industry, if maintained, may be a barrier to ICT diffusion in Scotland.

3.6 A Scottish knowledge economy league table

Examining the results for Scottish industries across all four measures of knowledge/skill content as shown in Table 7, it becomes apparent that a number of sectors, Research and Development, Computing Services, Insurance and Pension Funds and Education, consistently feature highly against each measure.

Table 7: Sectors that are consistently highly placed across knowledge content measures

Average NVQ Level Top 7 Industries		Proportion of employees with NVQ level 4/5. Top 7 Industries	Ratio of NVQ's Sold/Bought. Top 7 Industries	Concentration of Computer Related jobs. Top 7 Industries
1	Research and Development	Education	Research and Development	Computing Services
2	Computing Services	Computing Services	Computing Services	Insurance and Pension Funds
3	Education	Research and Development	Education	Office Machinery and Computers
4	Insurance and Pension Funds	Health, Social Work and Veterinary Services	Auxiliary to Insurance and Financial Services	Gas and Electricity Production and Distribution
5	Auxiliary to Insurance and Financial Services	Insurance and Pension Funds	Medical and Precision Instruments	Research and Development
6	Gas and Electricity Production and Distribution	Gas and Electricity Production and Distribution	Health, Social Work and Veterinary Services	Banking, Financial Intermediation
7	Extraction - Oil and Gas	Business Services	Insurance and Pension Funds	Postal and Telecommunications Services

By combining the results for all four measures and giving each measure an equal weighting, a 'Scottish knowledge economy league table' can be developed. Ranking is determined by a sector being allocated 5 points for a placing in the top five on any measure, 4 points for a place between 6 -10, 3 points for a place between 11-15, 2 points for a placing between 16-20 ,1 point for a placing between 21-25 and 0 points for all placings below 25. The results are shown in Table 8.

Table 8: A Scottish Knowledge Economy League Table

Rank	SIC	Description	pts
1	73	Research and Development	20
-	72	Computing Services	20
3	66	Insurance and Pension Funds	19
4	33	Medical and Precision Instruments	17
-	40	Gas and Electricity Production and Distribution	17
-	67	Auxiliary to Insurance and Financial Services	17
7	11,12	Extraction - Oil and Gas	15
-	80	Education	15
9	74	Business Services	13
10	85	Health, Social Work and Veterinary Services	12
11	41	Water Supply	10
-	29	Machinery, Tools and Appliances	10
-	65	Banking, Financial Intermediation	10
14	22	Printing and Publishing	9
-	70	Owning and Dealing in Real Estate	9
16	35	Building and Repair of Sea, Air and Spacecraft	8
17	75	Public Administration	7
-	23	Oil Processing, Nuclear Fuel	7
-	30	Office Machinery and Computers	7
20	61	Water Transport	6
-	24	Chemical Products	6
22	91	Membership Organisations	5
-	32	Electronic Components	5
24	16	Tobacco	4
-	64	Postal and Telecommunications Services	4
-	14	Other Mining and Quarrying	4
-	31	Electrical Equipment	4
-	62	Air Transport	4
29	92	Recreational Services	3
-	28	Fabricated and Structural Metal Products	3
31	90	Sanitary Services	2
-	21	Paper and Board Products	2
33	71	Renting of Machinery	1
-	93	Other Service Activities	1
-	15	Food and Drink	1
-	45	Construction	1
-	10	Coal Extraction etc	1

This ranking of industry sectors according to their overall showing against the four knowledge measures provides an indication of where the highest levels of knowledge and skill actually reside in Scottish industry; therefore, it can be argued that this is a ranking of Scotland's genuine 'knowledge industries'. The highest possible score to be achieved is 20 points.

Under this ranking, 37 Scottish industry sectors achieved a score of one or above but only 10 scored more than 10 points. Two industries (Research and Development and Computing Services) scored the maximum possible. It can be noted that of the top ten industries, 7 are from the service sector, 2 are from the energy sector and only one is from manufacturing. If one compares this ranking with the OECD indicators of the 'knowledge economy' as reflected through global volume of technology intensity, it can be observed that only one OECD-defined high technology manufacturing industry (Medical and Precision instruments) scores highly as a Scottish knowledge industry.

Some service sector industries fair somewhat better, with 5 OECD-defined 'knowledge intensive' market services also ranking in the top ten of this Scottish Knowledge economy league table (Research and Development, Computing Services, Insurance and Pension Funds, Auxiliary to Insurance and Financial Services, and Business Services). Two of the remaining top ten Scottish 'knowledge industries', Education and Health, would also match the OECD's definition of knowledge intensity albeit that these are not regarded by the OECD as 'market' services. However the Scottish Knowledge Economy league table also reveals two Scottish energy sector industries with high knowledge content (Gas and Electricity and Oil and Gas Extraction) which would be invisible under the OECD indicators.

It is also worth highlighting that some industries currently classified as knowledge industries by the OECD *do not* rank highly on this Scottish Knowledge Economy league table. For example, Postal and Telecommunications Services only scores 4 points out of a possible 20. This sector may be an intensive *user* of technology; however, on examining its placings against all four knowledge indicators it can be observed that this industry only gains points for the proportion of its employees in ICT occupations (Measure Four) and scores zero points in terms of the NVQ skill levels of its workforce and for its Skilled Added Ratio. This would suggest that in practice the particular use that this Scottish industry makes of ICT does not utilise high domestic skill.

Looking at some of the manufacturing industries currently defined by the OECD as knowledge economy industries, Computer Manufacturing only scores 7 points for its Scottish knowledge content and Electrical equipment only scores 4 points. The Motor Vehicle industry does not score any points *at all*, and therefore under these measures cannot be considered to be a *Scottish* knowledge industry.

Table 9 lists the Scottish industries that did not achieve any points under the four knowledge indicators.

Table 9: Non-ranking Scottish industries

Rank	SIC	Description	pts
-	01	Agriculture	0
-	02	Forestry	0
-	02	Fishing	0
-	17.1 –17.7	Textiles	0
-	18	Wearing Apparel	0
-	19.1-19.3	Leather	0
-	20	Timber and Wood Products	0
-	25.1 –25.2	Rubber and Plastic Products	0
-	26.1-26.8	Glass, Ceramics, Bricks and Concrete	0
-	27.1-27.5	Basic Metal Goods	0
-	34	Motor Vehicles	0
-	36.1-37	Furniture and other Miscellaneous Manufacturing	0
-	50	Distribution and Motor Repair	0
-	51	Wholesale Distribution	0
-	52	Retail Distribution	0
-	55	Hotels, Catering, Pubs etc	0
-	60.1 –60.3	Railways and other Land Transport	0
-	63	Transport Services	0
-	95	Domestic Services	0

The comparison of OECD-defined knowledge industries with those emerging as Scottish knowledge industries under the four measures discussed reveals that there is some degree of commonality. However, while it is reassuring that areas of overlap exists, the comparison also reveals that global definitions and indicators of knowledge economy industries are not totally congruent with where the actual knowledge capacity is to be found at a regional level. The above measures of Scotland's knowledge content would suggest that the development of Scotland's knowledge economy is less likely to be dependent on the encouragement of high technology industries per se and more likely to flourish if the capacity of other industry sectors, particularly certain service industries and energy sector industries, is fully exploited.

It can also be noted that some of the industries which do not score at all against these measures of Scottish knowledge capacity are among those which currently attract significant policy attention - such as Agriculture, or a number of industries associated with Tourism (such as Hotels, Catering and Transport). These industries may be of importance to Scotland for a variety of reasons; however this analysis suggests that they cannot be considered as 'industries of the future' in terms of their importance to a *knowledge* economy.

4. Conclusion

Trying to secure an exact definition of the term knowledge economy is akin to determining when exactly the Industrial Revolution began - there is a mountain of descriptive material and near-universal acceptance of its existence (and importance) but a lack of clarity in determining its origins and/or its current dimensions.

As has been discussed, OECD measures of both volume and trade in high and medium technology manufacturing sectors are frequently used as a proxy for measuring the growth of the 'knowledge economy'. This is based on an assumption that the existence of such technology sectors is a strong indicator of knowledge capacity, since high technology goods are a physical embodiment of the knowledge that produced them. While these measures have some validity at a global level, they become less meaningful when applied to individual nations and regions since they do not disaggregate the processes from the product or give any weighting to the particular type of activity within such sectors that is carried out within a specific geographical region.

For example, under the OECD measures, the existence of a computer assembly plant would qualify as evidence of 'knowledge capacity' and signal the presence of 'knowledge economy' activity in a particular region since computer manufacturing is a 'High Technology' industry. This would be irrespective of whether all of the components were imported from outside that region and the regional computer plant operatives simply put them together and boxed them, with no greater skill required than that to assemble other products which are not classified as 'high technology'.

The OECD measures for service sector activity also do not solve the problem of measuring knowledge capacity within the service sector and indeed the activity of a number of industries, such as those in the energy sector, are not reflected at all using the OECD indicators. Other supplementary OECD indicators of knowledge-based activity are grounded in relatively narrow measures of knowledge investment (in R&D, higher education and software). These do not seek to identify the knowledge *content* of a particular industry or occupational group, which is a key factor at regional level in identifying whether the activity in which a region engages is genuinely skilled.

Current Scottish economic policy has developed additional indicators to seek to clarify this problem - such as including any firms or sectors that exhibit a global presence, the rate of productivity growth, the volume of e-transactions and expenditure on in-work training as well as on Research and Development.

There has also been considerable emphasis in Scotland on seeking to increase the general stock of '*know-what* and *know-why*' through raising participation rates in post-compulsory education as well as the stock of 'know-how' through in-work training. A cluster strategy has been developed to encourage potential knowledge spill-overs and agglomerations of skill through networked knowledge or *know-who* among industrial groups that are thought to have potential for the future.

However as policies intended to promote the growth of a *Scottish* Knowledge Economy these approaches remain faintly blunt instruments; they are not necessarily predicated on evidence of where the current Scottish stock of skills or knowledge actually lie nor on evidence of where a stock of skills and knowledge is required or likely to be required. Combined with reliance on OECD measures of manufacturing industries as knowledge economy indicators, this can lead to particular industrial sectors being promoted as 'knowledge industries', irrespective of whether their actual processes or outputs utilise any significant input of 'Scottish Knowledge'.

For example, growth in exports may not automatically signal that there has been a growth in Scottish knowledge capacity. While at first sight it might be assumed that export growth means increasing competitiveness and therefore is somehow indicative of Scottish goods and services being at 'the cutting edge', a more reliable indicator may be the proportion of specifically *Scottish* content within those exports.

Otherwise it is perfectly possible that an apparently major Scottish exporter of high technology goods is in fact doing little more than the industrial equivalent of post and packaging ; with all that is 'Scottish' being the postmark . If an industry is importing all the major components for its high technology product, the actual skilled Scottish content of the exported product may be minimal . If the skilled Scottish content is minimal, then there will be no reason why that company should continue to operate in Scotland if another country offers a cheaper pool of unskilled or semi-skilled labour for its production line. This is exactly what promoting the growth of a knowledge economy in Scotland is intended to avoid.

Therefore the new four new measures proposed in this paper and the Knowledge Economy rankings thereby derived are intended to shed new light on where knowledge content and skill is actually to be found in the Scottish economy. The results derived from these measures are not of course an exact measure of Scotland's knowledge economy in terms of embodied skills. There are limitations to all measurements of knowledge capacity and a considerable proportion of embodied knowledge is likely to remain tacit and to defy quantification. However shifting the focus towards measuring knowledge content places a greater emphasis upon understanding the nature of the learning processes of an economy - both formal schooling, higher formal education and on-the-job training. If Scotland is able to signal clearly the level and specialisation of its knowledge base, while at the same time assisting those with low skills to move up the skills ladder, then demand for Scottish-based insights embodied within the people of Scotland is likely to grow.

In effect, the pursuit of knowledge economy status is a drive for competitive advantage. In the *weightless economy* competitive advantage is a consequence of intellect.[16] Those firms, sectors, regions and nations that can learn faster or better become more competitive because their knowledge is scarce and therefore cannot be immediately imitated by new entrants or transferred, via codified and formal channels, to competitor firms, regions, or nations.[17]

While an international definition of the knowledge economy such as that developed by the OECD can assist one in understanding the global dimensions of the knowledge economy phenomenon, it is less helpful in seeking to identify knowledge economy characteristics at a regional level. The development of a genuine knowledge economy at regional level will not simply result from encouraging the replication of a number of globally identified technology-based sectors across a region. It is more likely to depend on the growth and development of a region's particular skill and knowledge specialisations. Identifying the actual knowledge content of an economy and where the highest skills are being utilised is therefore an important factor in determining where regional knowledge economy activity exists.

[16] *Our Competitive Future: Building the Knowledge Driven Economy.* DTI Dec 1998

[17] M. Storper, *Institutions of the Knowledge-Based Economy,* School of Public Policy and Social Research, University of California, Los Angeles (1996).

Appendix 1: Summary of knowledge economy indicators

Table 3	Average NVQ content of Scottish workforce by industry sector
Table 4	Propensity of higher NVQ content in industry sectors
Table 5	Ratio of NVQs sold/bought by industry sector
Table 6	Concentration of ICT activity as measured by the concentration of occupational groups across Scottish industry. **126** (computer systems managers etc), **214** (software engineers), **320** (computer analysts/programmers), **490** (computer etc operators) and **526** (computer engineers) across Scottish industry.
Table 7	Knowledge economy league derived from four measures

Appendix 2: NVQ classifications

NVQ Level 5	Higher Degree.
NVQ Level 4	First Degree, Other Degree, Diploma in HE, HNC HND Higher BTEC, Teaching Further, Teaching Secondary, Teaching Primary, Nursing etc, Other higher qualifications, RSA Diploma.
NVQ Level 3	A Level & Equivalent, RSA Advanced Diploma, ONC OND BTEC etc, City & Guilds Advanced Craft, Scottish CSYS or equivalent (67%), SCE Higher or equivalent, Trade Apprentice (50%), Other qualification (10%).
NVQ Level 2	RSA Diploma City & Guilds Craft, BTECT Scotvec first or general certificate, O-level or equivalent, Trade Apprentice (50%), Scottish CSYS or equivalent (33%), Other qualification (35%).
NVQ Level 1	CSE below grade, BTEC etc general, YT YTP certificate, SCOTVEC national, RSA other qualifications, City & Guilds other, Other qualification (55%).
No Level	No qualification.

Level 5	Competence which involves the application of a range of fundamental principles across a wide and often unpredictable variety of contexts. Very substantial personal autonomy and often significant responsibility for the work of others and for the allocation of substantial resources features strongly, as do personal accountabilities for analysis, diagnosis, design, planning, execution and evaluation.
Level 4	Competence which involves the application of knowledge in a broad range of complex, technical or professional work activities performed in a variety of contexts and with a substantial degree of personal responsibility and autonomy. Responsibility for the work of others and the allocation of resources is often present.
Level 3	Competence which involves the application of knowledge in a broad range of varied work activities performed in a wide variety of contexts, most of which are complex and non-routine. There is considerable responsibility and autonomy and control or guidance of others is often required.
Level 2	Competence which involves the application of knowledge in a significant range of varied work activities, performed in a variety of contexts. Some of these activities are complex or non-routine and there is some individual responsibility or autonomy. Collaboration with others, perhaps through membership of a work group or team, may often be a requirement.
Level 1	Competence which involves the application of knowledge in the performance of a range of varied work activities, most of which may be routine and predictable. **Definition: NVQ's are work-related, competence based qualifications** **NVQ’s reflect the skills and knowledge needed to do a job effectively** **NVQ’s represent national standards recognised by employers throughout the country**

Appendix 3: Results for all four Knowledge Economy indicators

Average NVQ Level Top 25 Industries			Proportion of employees with NVQ level 4/5. Top 25 Industries			Ratio of NVQ's Sold/Bought. Top 25 Industries			Concentration of Computer Related jobs. Top 25 Industries		
1	Research and Development	3.49	1	Education	61.33%	1	Research and Development	1.47	1	Computing Services	58.82%
2	Computing Services	3.35	2	Computing Services	60.83%	2	Computing Services	1.34	2	Insurance and Pension Funds	11.20%
3	Education	3.23	3	Research and Development	60.23%	3	Education	1.31	3	Office Machinery and Computers	11.06%
4	Insurance and Pension Funds	2.85	4	Health, Social Work and Veterinary Services	38.88%	4	Auxiliary to Insurance and Financial Services	1.18	4	Gas and Electricity Production and Distribution	8.94%
5	Auxiliary to Insurance and Financial Services	2.82	5	Insurance and Pension Funds	34.36%	5	Medical and Precision Instruments	1.16	5	Research and Development	7.79%
6	Gas and Electricity Production and Distribution	2.74	6	Gas and Electricity Production and Distribution	31.96%	6	Health, Social Work and Veterinary Services	1.15	6	Banking, Financial Intermediation	7.65%
7	Extraction - Oil and Gas	2.73	7	Business Services	31.71%	7	Insurance and Pension Funds	1.13	7	Postal and Telecommunications Services	6.37%
8	Medical and Precision Instruments	2.69	8	Extraction - Oil and Gas	31.70%	-	Extraction - Oil and Gas	1.13	8	Other Mining and Quarrying	5.56%
9	Water Supply	2.63	9	Auxiliary to Insurance and Financial Services	30.97%	9	Gas and Electricity Production and Distribution	1.11	9	Medical and Precision Instruments	5.26%
10	Business Services	2.59	10	Medical and Precision Instruments	29.91%	10	Business Services	1.07	10	Air Transport	5.00%
11	Public Administration	2.58	11	Water Supply	29.14%	-	Building and Repair of Sea, Air and Spacecraft	1.07	11	Electrical Equipment	4.85%
-	Health, Social Work and Veterinary Services	2.58	12	Owning and Dealing in Real Estate	28.93%	12	Water Supply	1.05	12	Printing and Publishing	4.35%
13	Banking, Financial Intermediation	2.57	13	Chemical Products	27.38%	-	Machinery, Tools and Appliances	1.05	13	Auxiliary to Insurance and Financial Services	3.67%
14	Owning and Dealing in Real Estate	2.56	14	Membership Organisations	26.07%	14	Printing and Publishing	1.04	14	Electronic Components	3.31%
15	Building and Repair of Sea, Air and Spacecraft	2.55	15	Machinery, Tools and Appliances	24.32%	-	Owning and Dealing in Real Estate	1.04	15	Extraction - Oil and Gas	2.78%
16	Machinery, Tools and Appliances	2.52	16	Public Administration	23.62%	16	Fabricated and Structural Metal Products	1.03	-	Sanitary Services	2.78%
17	Oil Processing, Nuclear Fuel	2.50	17	Banking, Financial Intermediation	22.95%	-	Water Transport	1.03	17	Water Transport	2.50%
18	Printing and Publishing	2.46	18	Electronic Components	22.46%	-	Chemical Products	1.03	18	Oil Processing, Nuclear Fuel	2.44%
19	Tobacco	2.44	19	Office Machinery and Computers	21.89%	19	Recreational Services	1.02	19	Machinery, Tools and Appliances	2.31%
20	Water Transport	2.41	20	Oil Processing, Nuclear Fuel	21.71%	20	Banking, Financial Intermediation	1.01	20	Paper and Board Products	2.27%
21	Chemical Products	2.39	21	Printing and Publishing	20.04%	-	Membership Organisations	1.01	21	Food and Drink	2.26%
-	Fabricated and Structural Metal Products	2.39	22	Tobacco	19.56%	22	Tobacco	1.00	22	Building and Repair of Sea, Air and Spacecraft	2.13%
23	Membership Organisations	2.38	23	Building and Repair of Sea, Air and Spacecraft	19.35%	-	Oil Processing, Nuclear Fuel	1.00	23	Other Service Activities	2.04%
24	Construction	2.34	24	Electrical Equipment	19.04%	-	Public Administration	1.00	24	Public Administration	1.90%
25	Renting of Machinery	2.31	25	Recreational Services	18.92%	-	Coal Extraction etc	1.00	-	Business Services	1.90%

Appendix 4: Bibliography

M Blaug, *Economics of Education*, Penguin Books Ltd, Harmondsworth (1971).

J. Burke (ed) *Competency Based Education and Training*, The Falmer Press London (1989).

D. Colardyn, *Assessment and Recognition of Skills and Competencies: Developments in France, Further Education and Training of the Labour Force*, OECD/GD(90) 6 (1990).

Alessandra Colecchia and Paul Schreyer, *OECD Working Paper: ICT Investment & Economic Growth In The 1990s: Is the US a unique case? A comparative study of nine OECD Countries* (2001). http://www.olis.oecd.org/olis/2001doc.nsf/LinkTo/DSTI-DOC(2001)7

W. Coyle, *International Relocation*, Butterworth-Heinemann Ltd. Oxford (1992).

P. David, Knowledge, *Property and the System Dynamics of Technological Change*. Proceedings of the World Bank Annual Conference on Development Economics (1993).

Davis, G.B., & Olson, M.H. *Management Information Systems*. McGraw-Hill, New York (1985).

Department for Education & Skills, *History & Background of NVQ's*, (2002) http://www.dfes.gov.uk/nvq/history.shtml

Department for Education & Skills. *Definitions of NVQ/SVQ Levels*, (2002). http://www.dfes.gov.uk/nvq/what.shtml

DTI Publication: *Our Competitive Future: Building the Knowledge Driven Economy*. (1998) http://www.dti.gov.uk

DTI Publication: DTI Regional Competitiveness Report (2001) http://www.dti.gov.uk

G Eliasson et-al, *The Knowledge- Based Information Economy*, Almqvist & Wiksell International, Stockholm, (1990).

European Economy: *The contribution of information and communication technologies to growth in Europe and the US: A macroeconomic analysis*. Supplement A, Economic trends. No 12 - December (2000).

E. Fennel *Be Judged on Your Ability to Do the Job, The Schools Fair*. The Times London June 24, (1993).

D Foray & B.A Lundvall. *The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy*. OECD Document, Employment & Growth in the Knowledge-based Economy, (1996).

D.R. Howell and E.N. Wolff, *Technical Change and the Demand for Skills by US Industries*, Cambridge Journal of Economics, Vol 16, No2, June.

Lundvall, B.A and B. Johnson, *The Learning Economy*, Journal of Industry Studies, Vol. 1. No. 2 December, (1994).

McNicoll I,Melling M and Marsh R, *The Scottish Labour Market Intelligence Project* 1999

McNicoll I,Marsh R and Kelly U, *The Scottish Labour Market Intelligence Model Professional Edition* 2001

Office of National Statistics. http://www.statistics.gov.uk/

Office of National Statistics: *LFS Introduction & Methodology*, 2002 http://www.statistics.gov.uk/downloads/theme_labour/LFSUGvol1.pdf

National Training Information Service of Australia: http://www.ntis.gov.au/cgi-bin/waxhtml/~ntis2/std.wxh?page=

Dale Neef, *The Economic Impact of Knowledge*, Butterworth-Heinmann, (1998).

OECD in Figures (2000).

OECD Publication: *The Knowledge-Based Economy*. OCDE/GD(96)102 (1996).

OECD Publication: Report: *Measuring the ICT Sector* (2001)
http://www.oecd.org//dsti/sti/it/prod/measuring_ict.pdf

OECD Publication: *Measuring What People Know - Human Capital Accounting for the Knowledge Economy*, OECD (1996).

OECD Publication: *Science, Technology and Industry Scoreboard 2001 - Towards a knowledge-based economy* (2001). http://www1.oecd.org/publications/e-book/92-2001-04-1-2987/

Michael E Porter, *Competitive Strategy, Techniques for Analysing Industries and Competitors*, MacMillan Free Press, New York, (1980)

M. Porter, *The Competitive Advantage of Nations*, MacMillan Business Press, London. (1998a).

M. Porter, On Competition: *Clusters and Competition: New agendas for companies, governments and institutions*. (1998b)

S. Prais (ed), *Education and Training: Britain and Other Countries Compared*. National Institute of Economic and Social Research, Productivity, London, (1989).

L. Prusak and D. Cohen, *Knowledge Buyers, Sellers, and Brokers: The Political Economy of Knowledge*. Reproduced in The Economic Impact of Knowledge, Butterworth-Heinemann (1998).

Robert Reich, *The Work of Nations*, Simon & Schuster Ltd. London (1998).

David Ricardo, *The Principles of Political Economy and Taxation*, first published in 1817.

Paul M Romer, *Two Strategies for Economic Development: Using Ideas and Producing Ideas*, World Bank (1993).

S. Suranovic, *International Trade Theory and Policy: The Ricardian Model of Comparative Advantage*. The International Economics Study Centre 1997. http://internationalecon.com/v1.0/ch40/ch40.html

Scottish Executive: *A Framework for Economic Development in Scotland* 2000

Scottish Executive : *Measuring Scotland's Progress towards Smart, Successful Scotland*, (2001)
http://www.scotland.gov.uk/consultations/lifelonglearning/progress_smart.pdf

Scottish Executive: *Scottish Economic Statistics* 2002

Scottish Executive : *A Skills Strategy for a Competitive Scotland*, (1999).

Scottish Executive : *Skills for Scotland*, (1999). http://www.scotland.gov.uk

M. Storper, *Institutions of the Knowledge-Based Economy*, School of Public Policy and Social Research, University of California, Los Angeles (1996).

Adrian Wood, *North-South Trade, Employment and Inequality. Changing Fortunes in a Skill-Driven World*, Clarendon Press, Oxford, (1994).